―SCIENCE―

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CELESTIAL PHYSICS.[1]

(Continued from p. 234.)

BESIDES its more direct use in the chemical analysis of the heavenly bodies, the spectroscope has given to us a great and unexpected power of advance along the lines of the older astronomy. In the future a higher value may, indeed, be placed upon the indirect use of the spectroscope than upon its chemical relations.

By no direct astronomical methods could motions of approach or of recession of the stars be even detected, much less could they be measured. A body coming directly towards us or going directly from us appears to stand still. In the case of the stars we can receive no assistance from change of size or of brightness. The stars show no true disks in our instruments, and the nearest of them is so far off that if it were approaching us at the rate of a hundred miles in a second of time, a whole century of such rapid approach would not do more than increase its brightness by the one-fortieth part.

Still it was only too clear that so long as we were unable to ascertain directly those components of the stars' motions which lie in the line of sight, the speed and direction of the solar motion in space, and many of the great problems of the constitution of the heavens, must remain more or less imperfectly known. Now the spectroscope has placed in our hands this power, which, though so essential, appeared almost in the nature of things to lie forever beyond our grasp: it enables us to measure directly, and under favorable circumstances to within a mile per second, or even less, the speed of approach or of recession of a heavenly body. This method of observation has the great advantage for the astronomer of being independent of the distance of the moving body, and is therefore as applicable and as certain in the case of a body on the extreme confines of the visible universe, so long as it is bright enough, as in the case of a neighboring planet.

Doppler had suggested as far back as 1841 that the same principle on which he had shown that a sound should become sharper or flatter if there were an approach or a recession between the ear and the source of the sound, would apply equally to light; and he went on to say that the difference of color of some of the binary stars might be produced in this way by their motions. Doppler was right in that the principle is true in the case of light, but he was wrong in the particular conclusion which he drew from it. Even if we suppose a star to be moving with a sufficiently enormous velocity to alter sensibly its color to the eye, no such change would actually be seen, for the reason that the store of invisible light beyond both limits of the visible spectrum, the blue and the red, would be drawn upon, and light-waves invisible to us would be exalted or degraded so as to take the place of those raised or lowered in the visible region, and the color of the star would remain unchanged. About eight years later Fizeau pointed out the importance of considering the individual wave-lengths of which white light is composed. As soon, however, as we had learned to recognize the lines of known substances in the spectra of the heavenly bodies, Doppler's principle became applicable as the basis of a new and most fruitful method of investigation. The measurement of the small shift of the celestial bodies from their true positions, as shown by the same lines in the spectrum of a terrestrial substance, gives to us the means of ascertaining directly in miles per second the speed of approach or of recession of the heavenly body from which the light has come.

An account of the first application of this method of research to the stars, which was made in my observatory in 1868, was given by Sir Gabriel Stokes from this chair at the meeting at Exeter in 1869. The stellar motions determined by me were shortly after confirmed by Professor Vogel in the case of Sirius, and in the case of other stars by Mr. Christie, now astronomer-royal, at Greenwich; but, necessarily, in consequence of the inadequacy of the instruments then in use for so delicate an inquiry, the amounts of these motions were but approximate.

The method was shortly afterwards taken up systematically at Greenwich and at the Rugby Observatory. It is to be greatly regretted that, for some reasons, the results have not been sufficiently accordant and accurate for a research of such exceptional delicacy. On this account probably, as well as that the spectroscope at that early time had scarcely become a familiar instrument in the observatory, astronomers were slow in availing themselves of this new and remarkable power of investigation. That this comparative neglect of so truly wonderful a method of ascertaining what was otherwise outside our powers of observation has greatly retarded the progress of astronomy during the last fifteen years, is but too clearly shown by the brilliant results which within the last couple of years have followed fast upon the recent masterly application of this method by photography at Potsdam, and by eye with the needful accuracy at the Lick Observatory. At last this use of the spectroscope has taken its true place as one of the most potent methods of astronomical research. It gives us the motions of approach and of recession, not in angular measures, which depend for their translation into actual velocities upon separate determinations of parallactic displacements, but at once in terrestrial units of distance.

This method of work will doubtless be very prominent in the astronomy of the near future, and to it probably we shall have to look for the more important discoveries in sidereal astronomy which will be made during the coming century.

In his recent application of photography to this method of determining celestial motions, Professor Vogel, assisted by Dr. Scheiner, considering the importance of obtaining the spectrum of as many stars as possible on an extended scale without an exposure inconveniently long, wisely determined to limit the part of the spectrum on the plate to the region for which the ordinary silver-bromide gelatine plates are most sensitive,— namely, to a small distance on each side of

[1] Inaugural address at the meeting of the British Association for the Advancement of Science, at Cardiff, August, 1891, by William Huggins, president of the association (Nature, Aug. 20).

G,— and to employ as the line of comparison the hydrogen line near G, and recently also certain lines of iron. The most minute and complete mechanical arrangements were provided for the purpose of securing the absolute rigidity of the comparison spectrum relatively to that of the star, and for permitting temperature adjustments and other necessary ones to be made.

The perfection of these spectra is shown by the large number of lines, no fewer than 250 in the case of Capella, within the small region of the spectrum on the plate. Already the motions of about fifty stars have been measured with an accuracy, in the case of a large number of them, of about an English mile per second.

At the Lick Observatory it has been shown that observations can be made directly by eye with an accuracy equally great. Mr. Keeler's brilliant success has followed in great measure from the use of the third and fourth spectra of a grating 14,438 lines to the inch. The marvellous accuracy attainable in his hands on a suitable star is shown by observations on three nights of the star Arcturus, the largest divergence of his measures being not greater than six-tenths of a mile per second, while the mean of the three nights' work agreed with the mean of five photographic determinations of the same star at Potsdam to within one-tenth of an English mile. These are determinations of the motions of a sun so stupendously remote that even the method of parallax practically fails to fathom the depth of intervening space, and by means of light-waves which have been, according to Elkin's nominal parallax, nearly two hundred years upon their journey.

Mr. Keeler, with his magnificent means, has accomplished a task which I attempted in vain in 1874, with the comparatively poor appliances at my disposal, of measuring the motions in the line of sight of some of the planetary nebulæ. As the stars have considerable motions in space, it was to be expected that nebulæ should possess similar motions, for the stellar motions must have belonged to the nebulæ out of which they have been evolved. My instrumental means, limiting my power of detection to motions greater than twenty-five miles per second, were insufficient. Mr. Keeler has found, in the examination of ten nebulæ, motions varying from two miles to twenty-seven miles, with one exceptional motion of nearly forty miles.

For the nebula of Orion, Mr. Keeler finds a motion of recession of about ten miles a second. Now this motion agrees closely with what it should appear to have from the drift of the solar system itself, so far as it has been possible at present to ascertain the probable velocity of the sun in space. This grand nebula, of vast extent and of extreme tenuity, is probably more nearly at rest relatively to the stars of our system than any other celestial object we know; still it would seem more likely that even here we have some motion, small though it may be, than that the motions of the matter of which it is formed were so absolutely balanced as to leave this nebula in the unique position of absolute immobility in the midst of whirling and drifting suns and systems of suns.

The spectroscopic method of determining celestial motions in the line of sight has recently become fruitful in a new but not altogether unforeseen direction, for it has, so to speak, given us a separating power far beyond that of any telescope the glass-maker and the optician could construct, and so enabled us to penetrate into mysteries hidden in stars apparently single, and altogether unsuspected of being binary systems. The spectroscope has not simply added to the list of the known binary stars, but has given to us for the first time a knowledge of a new class of stellar systems, in which the components are in some cases of nearly equal magnitude, and in close proximity, and are revolving with velocities greatly exceeding the planetary velocities of our system.

The K line in the photographs of Mizar, taken at the Harvard College Observatory, was found to be double at intervals of fifty-two days. The spectrum was therefore not due to a single source of light, but to the combined effect of two stars moving periodically in opposite directions in the line of sight. It is obvious that if two stars revolve round their common centre of gravity in a plane not perpendicular to the line of sight, all the lines in a spectrum common to the two stars will appear alternately single or double.

In the case of Mizar and the other stars to be mentioned, the spectroscopic observations are not as yet extended enough to furnish more than an approximate determination of the elements of their orbits.

Mizar especially, on account of its relatively long period, — about 105 days,— needs further observations. The two stars are moving each with a velocity of about fifty miles a second, probably in elliptical orbits, and are about a hundred and forty-three millions of miles apart. The stars, of about equal brightness, have together a mass about forty times as great as that of our sun.

A similar doubling of the lines showed itself in the Harvard photographs of β Aurigæ at the remarkably close interval of almost exactly two days, indicating a period of revolution of about four days. According to Vogel's later observations, each star has a velocity of nearly seventy miles a second, the distance between the stars being little more than seven and a half millions of miles, and the mass of the system 4.7 times that of the sun. The system is approaching us at the speed of about sixteen miles a second.

The telescope could never have revealed to us double stars of this order. In the case of β Aurigæ, combining Vogel's distance with Pritchard's recent determination of the star's parallax, the greatest angular separation of the stars as seen from the earth would be one two-hundredth part of a second of arc, and therefore very far too small for the highest powers of the largest telescopes. If we take the relation of aperture to separating power usually accepted, an object-glass of about eighty feet in diameter would be needed to resolve this binary star. The spectroscope, which takes no note of distance, magnifies, so to speak, this minute angular separation four thousand times; in other words, the doubling of the lines, which is the phenomenon that we have to observe, amounts to the easily measurable quantity of twenty seconds of arc.

There were known, indeed, variable stars of short period, which it had been suggested might be explained on the hypothesis of a dark body revolving about a bright sun in a few days, but this theory was met by the objection that no such systems of closely revolving suns were known to exist.

The Harvard photographs of which we have been speaking were taken with a slitless form of spectroscope, the prisms being placed, as originally by Fraunhofer, before the object-glass of the telescope. This method, though it possesses some advantages, has the serious drawback of not permitting a direct comparison of the star's spectrum with terrestrial spectra. It is obviously unsuited to a variable star like Algol, where one star only is bright, for in such a case there would be no doubling of the lines, but only a small shift to and fro of the lines of the bright star as it moved in its orbit alter-

nately towards and from our system, which would need for its detection the fiducial positions of terrestrial lines compared directly with them.

For such observations the Potsdam spectrograph was well adapted. Professor Vogel found that the bright star of Algol did pulsate backwards and forwards in the visual direction in a period corresponding to the known variation of its light. The explanation which had been suggested for the star's variability, that it was partially eclipsed at regular intervals of 68.8 hours by a dark companion large enough to cut off nearly five-sixths of its light, was therefore the true one. The dark companion, no longer able to hide itself by its obscureness, was brought out into the light of direct observation by means of its gravitational effects.

Seventeen hours before minimum, Algol is receding at the rate of about 24½ miles a second, while seventeen hours after minimum it is found to be approaching with the speed of about 28½ miles. From these data, together with those of the variation of its light, Vogel found, on the assumption that both stars have the same density, that the companion, nearly as large as the sun, but with about one-fourth his mass, revolves with a velocity of about fifty-five miles a second. The bright star, of about twice the size and mass, moves about the common centre of gravity with the speed of about twenty-six miles a second. The system of the two stars, which are about three and a half millions of miles apart, considered as a whole, is approaching us with a velocity of 2.4 miles a second. The great difference in luminosity of the two stars, not less than fifty times, suggests rather that they are in different stages of condensation, and dissimilar in density.

It is obvious that if the orbit of a star with an obscure companion is inclined to the line of sight, the companion will pass above or below the bright star, and produce no variation of its light. Such systems may be numerous in the heavens. In Vogel's photographs, Spica, which is not variable, by a small shifting of its lines reveals a backward and forward periodical pulsation due to orbital motion. As the pair whirl round the common centre of gravity, the bright star is sometimes advancing, at others receding. They revolve in about four days, each star moving with a velocity of about fifty-six miles a second in an orbit probably nearly circular, and possess a combined mass of rather more than two and a half times that of the sun. Taking the most probable value for the star's parallax, the greatest angular separation of the stars would be far too small to be detected with the most powerful telescopes.

If in a close double star the fainter companion is of the white-star type, while the bright star is solar in character, the composite spectrum would be solar with the hydrogen lines unusually strong. Such a spectrum would itself afford some probability of a double origin, and suggest the existence of a companion star.

In the case of a true binary star the orbital motions of the pair would reveal themselves in a small periodical swaying of the hydrogen lines relatively to the solar ones.

Professor Pickering considers that his photographs show ten stars with composite spectra; of these, five are known to be double The others are: τ Persei, ζ Aurigæ, δ Sagittarii, 31 Ceti, and β Capricorni. Perhaps β Lyræ should be added to this list.

In his recent classical work on the rotation of the sun, Dunér has not only determined the solar rotation for the equator but for different parallels of latitude up to 75°. The close accordance of his results shows that these observations are sufficiently accurate to be discussed with the variation of the solar rotation for different latitudes which had been determined by the older astronomical methods from the observations of the solar spots.

Though I have already spoken incidentally of the invaluable aid which is furnished by photography in some of the applications of the spectroscope to the heavenly bodies, the new power which modern photography has put into the hands of the astronomer is so great, and has led already, within the last few years, to new acquisitions of knowledge of such vast importance, that it is fitting that a few sentences should be specially devoted to this subject.

Photography is no new discovery, being about half a century old: it may excite surprise, and indeed possibly suggest some apathy on the part of astronomers, that though the suggestion of the application of photography to the heavenly bodies dates from the memorable occasion when, in 1839, Arago, announcing to the Académie des Sciences the great discovery of Niepce and Daguerre, spoke of the possibility of taking pictures of the sun and moon by the new process, yet that it is only within a few years that notable advances in astronomical methods and discovery have been made by its aid.

The explanation is to be found in the comparative unsuitability of the earlier photographic methods for use in the observatory. In justice to the earlier workers in astronomical photography, among whom Bond, De la Rue, J. W. Draper, Rutherfurd, Gould, hold a foremost place, it is needful to state clearly that the recent great successes in astronomical photography are not due to greater skill, nor, to any great extent, to superior instruments, but to the very great advantages which the modern gelatine dry plate possesses for use in the observatory over the methods of Daguerre, and even over the wet collodion film on glass, which, though a great advance on the silver plate, went but a little way towards putting into the hands of the astronomer a photographic surface adapted fully to his wants.

The modern siver-bromide gelatine plate, except for its grained texture, meets the needs of the astronomer at all points. It possesses extreme sensitiveness; it is always ready for use; it can be placed in any position; it can be exposed for hours; lastly, it does not need immediate development, and for this reason can be exposed again to the same object on succeeding nights, so as to make up by several instalments, as the weather may permit, the total time of exposure which is deemed necessary.

Without the assistance of photography, however greatly the resources of genius might overcome the optical and mechanical difficulties of constructing large telescopes, the astronomer would have to depend in the last resource upon his eye. Now we cannot by the force of continued looking bring into view an object too feebly luminous to be seen at the first and keenest moment of vision. But the feeble light which falls upon the plate is not lost, but is taken in and stored up continuously. Each hour the plate gathers up 3,600 times the light-energy which it received during the first second. It is by this power of accumulation that the photographic plate may be said to increase, almost without limit, though not in separating power, the optical means at the disposal of the astronomer for the discovery of the observation of faint objects.

Two principal directions may be pointed out in which photography is of great service to the astronomer. It enables him within the comparatively short time of a single exposure to secure permanently with great exactness the

relative positions of hundreds or even of thousands of stars, or the minutest features of nebulæ or other objects, or the phenomena of a passing eclipse, a task which by means of the eye and hand could only be accomplished, if done at all, after a very great expenditure of time and labor. Photography puts it in the power of the astronomer to accomplish in the short span of his own life, and so enter into their fruition, great works which otherwise must have been passed on by him as a heritage of labor to succeeding generations.

The second great service which photography renders is not simply an aid to the powers the astronomer already possesses. On the contrary, the plate, by recording light-waves which are both too small and too large to excite vision in the eye, brings him into a new region of knowledge, such as the infra-red and the ultra-violet parts of the spectrum, which must have remained forever unknown but for artificial help.

The present year will be memorable in astronomical history for the practical beginning of the photographic chart and catalogue of the heavens, which took their origin in an international conference which met in Paris in 1887, by the invitation of M. l'Amiral Mouchez, director of the Paris Observatory.

The richness in stars down to the ninth magnitude of the photographs of the comet of 1882 taken at the Cape Observatory under the superintendence of Dr. Gill, and the remarkable star charts of the Brothers Henry which followed two years later, astonished the astronomical world. The great excellence of these photographs, which was due mainly to the superiority of the gelatine plate, suggested to these astronomers a complete map of the sky, and a little later gave birth in the minds of the Paris astronomers to the grand enterprise of an international chart of the heavens. The actual beginning of the work this year is in no small degree due to the great energy and tact with which the director of the Paris Observatory has conducted the initial steps, through the many delicate and difficult questions which have unavoidably presented themselves in an undertaking which depends upon the harmonious working in common of many nationalities, and of no fewer than eighteen observatories in all parts of the world. The three years since 1887 have not been too long for the detailed organization of this work, which has called for several elaborate preliminary investigations on special points in which our knowledge was insufficient, and which have been ably carried out by Professors Vogel and Bakhuyzen, Dr. Trépied, Dr. Scheiner, Dr. Gill, the astronomer royal, and others. Time also was required for the construction of the new and special instruments.

The decisions of the conference in their final form provide for the construction of a great photographic chart of the heavens with exposures corresponding to forty minutes' exposure at Paris, which it is expected will reach down to stars of about the fourteenth magnitude. As each plate is to be limited to four square degrees, and as each star, to avoid possible errors, is to appear on two plates, over twenty-two thousand photographs will be required. For the more accurate determination of the positions of the stars, a *réseau* with lines at distances of five millimetres apart is to be previously impressed by a faint light upon the plate, so that the image of the *réseau* will appear together with the images of the stars when the plate is developed. This great work will be divided, according to their latitudes, among eighteen observatories provided with similar instruments, though not necessarily constructed by the same maker. Those in the British dominions and at Tacubaya have been constructed by Sir Howard Grubb.

Besides the plates to form the great chart, a second set of plates for a catalogue is to be taken, with a shorter exposure, which will give stars to the eleventh magnitude only. These plates, by a recent decision of the permanent committee, are to be pushed on as actively as possible, though as far as may be practicable plates for the chart are to be taken concurrently. Photographing the plates for the catalogue is but the first step in this work, and only supplies the data for the elaborate measurements which have to be made, which are, however, less laborious than would be required for a similar catalogue without the aid of photography.

Already Dr. Gill has nearly brought to conclusion, with the assistance of Professor Kapteyn, a preliminary photographic survey of the southern heavens.

With an exposure sufficiently long for the faintest stars to impress themselves upon the plate, the accumulating action still goes on for the brighter stars, producing a great enlargement of their images from optical and photographic causes. The question has occupied the attention of many astronomers, whether it is possible to find a law connecting the diameters of these more or less over-exposed images with the relative brightness of the stars themselves. The answer will come out undoubtedly in the affirmative, though at present the empirical formulæ which have been suggested for this purpose differ from each other. Captain Abney proposes to measure the total photographic action, including density as well as size, by the obstruction which the stellar image offers to light

A further question follows as to the relation which the photographic magnitudes of stars bear to those determined by eye. Visual magnitudes are the physiological expression of the eye's integration of that part of the star's light which extends from the red to the blue. Photographic magnitudes represent the plate's integration of another part of the star's light — namely, from a little below where the power of the eye leaves off in the blue to where the light is cut off by the glass, or is greatly reduced by want of proper corrections when a refracting telescope is used. It is obvious that the two records are taken by different methods in dissimilar units of different parts of the star's light. In the case of certain colored stars the photographic brightness is very different from the visual brightness; but in all stars, changes, especially of a temporary character, may occur in the photographic or the visual region, unaccompanied by a similar change in the other part of the spectrum. For these reasons it would seem desirable that the two sets of magnitudes should be tabulated independently, and be regarded as supplementary of each other.

The determination of the distances of the fixed stars from the small apparent shift of their positions when viewed from widely separated positions of the earth in its orbit is one of the most refined operations of the observatory. The great precision with which this minute angular quantity — a fraction of a second only — has to be measured, is so delicate an operation with the ordinary micrometer, though, indeed, it was with this instrument that the classical observations of Sir Robert Ball were made, that a special instrument, in which the measures were made by moving the two halves of a divided object-glass, known as a heliometer, has been pressed into this service, and quite recently, in the skilful hands of Dr. Gill and Dr. Elkin, has largely increased our knowledge in this direction.

It is obvious that photography might be here of great ser-

vice, if we could rely upon measurements of photographs of the same stars taken at suitable intervals of time. Professor Pritchard, to whom is due the honor of having opened this new path, aided by his assistants, has proved by elaborate investigations that measures for parallax may be safely made upon photographic plates, with, of course, the advantages of leisure and repetition; and he has already by this method determined the parallax for twenty-one stars with an accuracy not inferior to that of values previously obtained by purely astronomical methods.

The remarkable successes of astronomical photography, which depend upon the plate's power of accumulation of a very feeble light acting continuously through an exposure of several hours, are worthy to be regarded as a new revelation. The first chapter opened when, in 1880, Dr. Henry Draper obtained a picture of the nebula of Orion; but a more important advance was made in 1883, when Dr. Common, by his photographs, brought to our knowledge details and extensions of this nebula hitherto unknown. A further disclosure took place in 1885, when the brothers Henry showed for the first time in great detail the spiral nebulosity issuing from the bright star Maia of the Pleiades, and, shortly afterwards, nebulous streams about the other stars of this group In 1886, Mr. Roberts, by means of a photograph to which three hours' exposure had been given, showed the whole background of this group to be nebulous. In the following year Mr. Roberts more than doubled for us the great extension of the nebular region which surrounds the trapezium in the constellation of Orion. By his photographs of the great nebula in Andromeda he has shown the true significance of the dark canals which had been seen by the eye. They are in reality spaces between successive rings of bright matter, which appeared nearly straight owing to the inclination in which they lie relatively to us. These bright rings surround an undefined central luminous mass. I have already spoken of this photograph.

Some recent photographs by Mr. Russell show that the great rift in the Milky Way in Argus, which to the eye is void of stars, is in reality uniformly covered with them. Also, quite recently, Mr. George Hale has photographed the prominences by means of a grating, making use of the lines H and K.

The heavens are richly but very irregularly inwrought with stars, the brighter stars cluster into well-known groups upon a background formed of an enlacement of streams and convoluted windings and intertwined spirals of fainter stars, which becomes richer and more intricate in the irregularly rifted zone of the Milky Way.

We, who form part of the emblazonry, can only see the design distorted and confused; here crowded, there scattered, at another place superposed. The groupings due to our position are mixed up with those which are real.

Can we suppose that each luminous point has no relation to the others near it than the accidental neighborship of grains of sand upon the shore, or of particles of the wind-blown dust of the desert? Surely every star, from Sirius and Vega down to each grain of the light-dust of the Milky Way, has its present place in the heavenly pattern from the slow evolving of its past. We see a system of systems, for the broad features of clusters and streams and spiral windings which mark the general design are reproduced in every part. The whole is in motion, each point shifting its position by miles every second, though from the august magnitude of their distances from us and from each other, it is only by the accumulated movements of years or of generations that some small changes of relative position reveal themselves.

The deciphering of this wonderfully intricate constitution of the heavens will be undoubtedly one of the chief astronomical works of the coming century. The primary task of the sun's motion in space, together with the motions of the brighter stars, has been already put well within our reach by the spectroscopic method of the measurement of star motions in the line of sight.

From other directions information is accumulating: from photographs of clusters and parts of the Milky Way, by Roberts in this country, Barnard at the Lick Observatory, and Russell at Sydney; from the counting of stars, and the detection of their configurations, by Holden and by Backhouse; from the mapping of the Milky Way by eye, at Parsonstown; from photographs of the spectra of stars, by Pickering at Harvard and in Peru; and from the exact portraiture of the heavens in the great international star chart which begins this year.

I have but touched some only of the problems of the newer side of astronomy. There are many others which would claim our attention if time permitted:—the researches of the Earl of Rosse on lunar radiation, and the work on the same subject and on the sun by Langley: observations of lunar heat with an instrument of his own invention by Mr. Boys; and observations of the variation of the moon's heat with its phase by Mr. Frank Very: the discovery of the ultra-violet part of the hydrogen spectrum, not in the laboratory, but from the stars: the confirmation of this spectrum by terrestrial hydrogen in part by H. W. Vogel, and in its all but complete form by Cornu, who found similar series in the ultra-violet spectra of aluminum and thallium: the discovery of a simple formula for the hydrogen series by Balmer: the important question as to the numerical spectral relationship of different substances, especially in connection with their chemical properties; and the further question as to the origin of the harmonic and other relations between the lines and the groupings of lines of spectra (on these points contributions during the past year have been made by Rudolf v. Kövesligethy, Ames, Hartley, Deslandres, Rydberg, Grünwald, Kayse and Runge, Johnstone Stoney, and others): the remarkable employment of interference phenomena by Professor Michelson for the determination of the size, and distribution of light within them, of the images of objects which when viewed in a telescope subtend an angle less than that subtended by the light-wave at a distance equal to the diameter of the objective,— a method applicable not alone to celestial objects, but also to spectral lines, and other questions of molecular physics.

Along the older lines there has not been less activity; by newer methods, by the aid of larger or more accurately constructed methods, by greater refinement of analysis, knowledge has been increased, especially in precision and minute exactness.

Astronomy, the oldest of the sciences, has more than renewed her youth. At no time in the past has she been so bright with unbounded aspirations and hopes. Never were her temples so numerous, nor the crowd of her votaries so great. The British Astronomical Association formed within the year numbers already about six hundred members. Happy is the lot of those who are still on the eastern side of life's meridian!

Already, alas! the original founders of the newer methods are falling out,— Kirchhoff, Angström, D'Arrest, Secchi, Draper, Becquerel,— but their places are more than filled:

the pace of the race is gaining, but the goal is not and never will be in sight.

Since the time of Newton our knowledge of the phenomena of nature has wonderfully increased, but man asks, perhaps more earnestly now than in his days, What is the ultimate reality behind the reality of the perceptions? Are they only the pebbles of the beach with which we have been playing? Does not the ocean of ultimate reality and truth lie beyond?

METEOROLOGICAL NOTES.

For many years the United States government has assiduously gathered up the meteorological conditions from many stations scattered far and wide over the surface of our great continent, and having collated the facts sent in to the central office, has deduced therefrom certain forecasts known as probabilities. These forecasts are made out twice per day, and then telegraphed broadcast over the country, to be disseminated among the people as widely as possible for the benefit of their commerce, their agriculture, their shipping, and even their lives. For many years I have been on the "volunteer" roster of the United States Weather Service, and as such have been the recipient of weather telegrams once per day. For several years I went to the trouble and expense to supply the usual flags, and faithfully made the proper display of them (at Fayette, Mo.).

In 1889 I saw in the St. Louis *Republic* a brief notice of a "whistle code" in use at Seymour, Ind., and I determined to introduce the whistle in place of the flags, and for the following considerations: (1) The flags could not be seen to any advantage beyond one mile; (2) in foggy weather or during snow-storms the flags could not be seen at all; (3) the whistle could be heard in any kind of weather and to distances reaching from six to eight miles in all directions, and by using a more powerful whistle the distance could be made greater still.

Accordingly I sent to Indiana and obtained the code in vogue there. It was a combination of short and long blasts, the "shorts" sometimes preceding and in other cases following the "longs." I concluded it would be more systematic to have the longs refer to the weather and come first, and the shorts refer to temperature and come last. The chief advantage in having shorts come last was that any one hearing a prolonged blast of the whistle might be sure that no short ones had preceded and been lost. I therefore adopted the following plan. Shorts refer to the temperature, one short meaning colder (the column in the thermometer gets shorter with cold), and two shorts meaning warmer. Longs refer to the weather, one long meaning fair (clear, or cloudy without precipitation), two longs meaning rain or snow. This much being decided upon, it is easy to blow "fair and warmer," or "snow and colder," or "fair and warmer followed by rain," — in the last the shorts come in the middle to separate the one long (fair) and the two long (rain), — or any other combination necessary. For the announcement of cold waves, three longs; and for frosts in the frosty seasons or for severe storms in summer, four longs, were used at Seymour, Ind., and the same were adopted in my code. In September, 1889, the first signal was blown, being preceded by four short blasts as a warning that the "weather" was about to be blown. From that date to this the people for miles around have been daily warned of the probabilities for the succeeding twenty-four hours, and they have shown much interest in the matter, being willing to put up at the mill, if necessary, a more powerful whistle than the one now employed.

One of our merchants had the code printed on his advertising cards, and they may be seen tacked up in stores or homes, or in the hands of citizens near and far. Many people soon commit the code to memory and have no need for the key. Persons have reported hearing the whistle at the distance of ten miles; but, as a rule, it is not regularly heard beyond five or six miles.

During the summer of 1890 I tried to get some of our railroads to adopt the code, and whistle the weather at intervals of five or six miles as the trains sped through the country. One road replied that they had too much whistling to do already, there were so many crossings along the way. But I still do not see why the weather whistle could not be used instead of the customary two longs and two shorts usually blown at crossings.

In the chief signal officer's report for 1890, p. 235, I am credited with the introduction of the whistle code now in use in many places in the State. In recent circulars sent out by Chief Harrington, I see that the code has been still further modified, the three longs being used to indicate "local rains," and three shorts meaning a "cold wave." As a cold wave comes rather under the head of temperature, it is doubtless more appropriate to include it among the shorts.

I have written thus at length about the whistle code because I think it should be widely introduced, entailing no expense for flags to be whipped out by the wind, and reaching more people than flags can. Moreover, by having the dispatch blown at the same hour every day, it becomes a time signal by which the people can set their clocks and watches. The noon hour is a good one where the morning forecasts can be delivered before twelve o'clock.

For several years, by the courtesy of the government, I was permitted to use a set of maximum and minimum thermometers. But they entailed the necessity of observation and adjustment every day, and this duty bound the observer to be at home or to intrust the instruments to other hands, or to break the continuity of his record. So last May one year ago I purchased a Draper self-recording thermometer, regulated it by comparisons with the standard instruments for several weeks, and then gave up these standard instruments.

For twelve months I replaced the charts week by week, and filed away the "red-lined" ones, with dates, etc., properly filled in the blanks therefor. On the first of July of this year (1891) I began to put those charts through again, using purple ink instead of red in the pen. Comparison of temperatures for 1890 and 1891, day by day, hour by hour, is both easy and interesting. I think I shall change the ink to green, or some other color, and use again another year. It is certainly a great comfort to wind up the clock, put in another chart, refill the pen, once per week (say Monday morning), and then go about one's business or on a journey, perhaps, and to know that there is to be no break in the record though away for days at a time. I would not like to go back to the old method again.

T. BERRY SMITH.

NOTES AND NEWS.

The Brooklyn Institute announces a series of "Institute Extension Courses," consisting of lectures on astronomy, by Mr. Garrett P. Serviss, president of the department of astronomy. The first course will be on the solar system, embracing "The Sun, Its Distance, Size, Motions, and Gravity;" "The Sun, Its Nature

and Constitution;" "The Earth as a Planet;" "Mercury, Venus, and Mars;" "Jupiter, Saturn, Uranus, and Neptune;" "The Satellites of the Planets;" and "Asteroids, Meteors, and Comets." The second of the series will deal with the stellar systems, and will consist of "The Geography of the Heavens;" "The Relation of the Solar System to Surrounding Space;" "The Stars, their Magnitudes, Distances, and Motions;" "The Stars, their Spectra and Constitution: Variable and Multiple Stars;" "Nebulæ and the Evolution of Stars;" and "The Constitution of the Universe." The third or advanced course will include "General Laws that Govern the Universe;" "Gravitation and the Perturbations of Planets;" "Light and its Analysis, — How Used as a Means of Investigation;" "Astronomical Photography;" "Electric and Magnetic Forces and their Application in Astronomy;" and "The Measurement of Time." The series will conclude with a course of three single lectures, on "The History of Astronomy;" "The Great Astronomers;" and "Recent Progress in Astronomical Research." Each of these lectures will be illustrated by lantern photographs. The courses are subject to alteration to meet special requirements. The institute will conduct these courses of lectures on the so-called "university extension" plan, under the title of "Institute Extension Lectures." Each lecture will be preceded by a conference on the subject of the previous lecture. A syllabus of each course of lectures, together with directions for reading and study, will be provided. Those who desire may present themselves for examination at the close of a course, by giving ten days' notice. Certificates will be issued by the institute to those who pass a satisfactory examination.

— According to *Nature*, an interesting experiment has been lately made by M. Chabry of the Société de Biologie, with regard to the pressure which can be produced by electrolytic generation of gas in a closed space. While the highest pressure before realized in this way was 447 atmospheres (Gassiot), M. Chabry has succeeded in getting as high as 1,200; and the experiment was broken off merely because the manometer used got cracked (without explosion). The electrolyzed liquid was a twenty-five per cent soda solution. Both electrodes were of iron: one was the hollow sphere in which the gas was collected, the other an inner concentric tube. The current had a strength of one and a half ampères, and was very constant during the experiment, which was merely one preliminary to a research in which very high pressures were desired.

— During the coming winter and spring a course of lectures, under the auspices of the New York Academy of Sciences, will be delivered in Hamilton Hall, Madison Avenue and 49th Street, this city. The lectures will be as follows: Oct. 26, Paraguay, the Land and the People, by Dr. Thomas Morong; Nov. 16, Woman's Part in the Earlier Civilizations, by Professor Otis T. Mason; Dec. 21, Mountains, their Origin and History, by Professor H. L. Fairchild; Jan. 18, The Lochs and Crannogs of Scotland, by Professor Franklin W. Hooper; Feb. 15, Street Scenes in Cairo and Glimpses of the Nile, by Professor H. Carrington Bolton; March 21, Contributions of Organic Chemistry to Modern Medicine, by Professor Arthur H. Elliott; April 18, Elves of the Air, by Dr. A. A. Julien; May 16, Color, by Professor Ogden N. Rood.

— At the twenty-fourth annual meeting of the Kansas Academy of Science, held at Ottawa, Oct. 14, 15, and 16, the following papers were read. "The Evolution of the Human Face," by A. H. Thompson; "Experiments made in 1891 on the Dissemination of the Chinch-Bug Diseases," F. H. Snow; "A New Erythronium (*E. mesochorum*)," by E. B. Knerr; "An Inexpensive Reagent Bottle for Use in Microscopic Work," by E. B. Knerr; "A Partial List of the Plants of Franklin County," by W. E. Castle; "Geographical Distribution of Common Western Plants" and "List of Rocky Mountain Plants collected in 1889," by M. A. Carlton; "On Solanum Rostratum," by L. E Sayre and W. S. Amos; "Is the Rainfall in Kansas increasing?" and "Seven-year Periodicity in Rainfall," by E. C. Murphy; "A Simple Method for the Determination of Equivalent Weights of Metals, as Compared with Hydrogen," E. B. Knerr; "Have Meteorites Magnetic Polarity?" by L. I. Blake; "A Revised List of Kansas Minerals," by G. H. Failyer and E. H. S. Bailey; "The Effect of Scientific Studies upon the Imagination," by Olin Templin; "Restoration of Pteranodon," by S. W. Williston; "Notes on Some New Kansas Cephalopods," by Robert Hay; "Some Statistics Relative to the Health of College Women," by Gertrude Crotty; "List of Diptera, Collected by F. H. Snow at Manitou Park, Col., August, 1891," by F. H. Snow and W. A. Snow; "New Western Diptera," by W. A. Snow; "Characteristic Flora" (second paper), "Some Prairie Plants of Eastern Colorado," and "Variations in Dominant Species of Plants," by M. A. Carlton;" "Doniphan Lake, formation of, in 1891," by E. B. Knerr; "Contributions to a List of Kansas Hymenoptera," by E. A. Popenoe; "On the Therapeutic Value of Some Recently Introduced Chemicals," by L. E. Sayre; "An Astronomical Lantern," by E. B. Knerr; "On the Corrosive Action of Fruit Juices on Tin Cans," by E. H. S. Bailey and E. C. Franklin; "Selective Absorption in Leaves," by A. G. Mayer; "Probable Temperature of Summer at Lawrence, Kan.," by E. C. Murphy; "Nesting of the Pied-billed Grebe" and "Two Rare Birds of Kansas, the White-faced Glossy Ibis, and Clark's Nutcracker," by A. M. Collett.

— The correspondent of the London *Times* at Alexandria, Egypt, states that three colossal statues, ten feet high, of rose granite, have just been found at Aboukir, a few feet below the surface. The discovery was made from indications furnished to the government by a local investigator, Daninos Pasha. The first two represent in one group Rameses II. and Queen Hentmara seated on the same throne. This is unique among Egyptian statues. The third statue represents Rameses standing upright in military attire, a sceptre in his hand and a crown upon his head. Both bear hieroglyphic inscriptions, and both have been thrown from their pedestals face downwards. Their site is on the ancient Cape Zephyrium, near the remains of the Temple of Venus at Arsinoe. Relics of the early Christians have been found in the same locality.

— The marine laboratory of biology and zoology, which is to be instituted at Bergen next year, *Nature* states, will be open to any foreign investigators who may desire to study the marine fauna of that part of Scandinavia.

— Professor N. S. Shaler has been appointed Dean of the Lawrence Scientific School of Harvard University, from which position Professor Chapin recently resigned to accept the directorship of Washington University, St. Louis, Mo.

— Professor Traill Green, M.D., LL.D., dean of the Pardee scientific department, and head of the chemical department of Lafayette College, at Easton, Pa., has retired from active service in the institution owing to advanced years. He has been made professor emeritus of the chemical department.

— Among other articles in the November *Magazine of American History* are "One Hundred Years of National Life; the Contrast between 1789 and 1889," by Dr. Patton; "Introduction of the Negro into the United States," by Rev. Dr. Stakely; and "The Historic Games of Old Canada," by Dr. Prosper Bender.

— Of the "Creole Studies," by Professor Hugo Schuchardt of Gratz in Styria, the latest issue is the ninth in the series, and deals with the Malayo-Portuguese medley language of Batavia and Tugu, on the island of Java. His serial is published in the octavo memoirs of the Imperial Academy of Sciences, Vienna, and in view of the rising interest paid to the studies of foreign languages, has attracted a good deal of attention. Among the medley languages, Schuchardt has taken up those that originated from the mixture of Romanic languages with those of the negroes, Malays, and other inhabitants of the African, Asiatic, and American coasts. In this line we mention his studies on the Negro-Portuguese of Annabom (West Africa), on the Annamito-French dialect, on the Indo-Portuguese of Mahé and Cannanore, and of other similar dialects of southern India, and on the Negro-Portuguese of Ilha do Principe (Gulf of Guinea). The ninth pamphlet of the series is, like the others, richly illustrated with vocabularies, popular songs, and other texts; the translation being added on the same page, we are enabled to judge more thoroughly upon the degree of mixture that has taken place between the European tongues and the native dialects.

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Attention is called to the "Wants" column. All are invited to use it in soliciting information or seeking new positions. The name and address of applicants should be given in full, so that answers will go direct to them. The "Exchange" column is likewise open.

COTTON-SEED MEAL IN THE DAIRY RATION.

IN bulletin No. 14 of the Texas Experiment Station is reported a series of experiments made to determine the influence of cotton-seed meal in the dairy ration on the creaming of milk, both by the common or gravity method and the centrifugal method.

In these experiments, cows were tested in lots containing several cows each, the cows in the contrasted lots being in as uniform a condition with respect to milk-flow, time from calving, etc., as it was possible to arrange them. The feed for each pair of contrasted lots was the same, except that one lot received equal parts of corn-meal and bran as bye food, while the other lot had cotton-seed meal and bran in equal parts.

In the case of two lots of five cows each that were far advanced in milk (100 to 124 days on the average) it was found that where the cream was raised by gravity at the ordinary summer temperature, the milk being set at about 70° in Fairlamb cans and skimmed when sour (in twelve to twenty-four hours), an average of 18.4 pounds of butter was lost in the skim-milk of the cows fed on cotton-seed meal for every hundred pounds present in the milk set, as againt 30.9 pounds lost when no cotton-seed or cotton-seed meal was fed.

In the case of two lots of four cows each, less advanced in milk (88 to 93 days) the loss of butter-fat in the skim milk on the cotton-seed meal ration was 22.7 pounds out of every hundred pounds actually present in the original milk, against 31.8 pounds lost when no cotton-seed meal was used.

In the case of two lots of three cows each that averaged but fifty days from calving at the beginning of the test, the loss was 11.3 pounds on cotton-seed meal ration, against 14.9 pounds when no cotton-seed was fed.

The average loss on cotton-seed meal for ordinary setting was therefore 17.5 pounds out of every hundred pounds present in the original milk, against 25.8 pounds lost when no cotton-seed meal was fed.

Where the milk of five cows, a hundred and fifty-two days from calving, was set at a temperature of 45°, and kept at this temperature with ice for twenty-four hours and then skimmed, the loss was 37.6 pounds out of every hundred pounds in the original milk, the cows having no cotton-seed meal; while five cows a hundred and thirty-two days from calving and having cotton-seed meal, lost but 22.9 pounds out of every hundred. When the milk was kept only twelve hours before skimming, the loss without cotton-seed meal was 49.1 pounds, against 31.7 pounds lost with cotton-seed meal, showing a decided advantage in the longer setting.

When the cream was extracted by the centrifugal method as soon as milked, that from four cows, two hundred and ten days from calving, showed a loss of but 1.8 pounds without cotton-seed, and that from four cows, two hundred and eleven days from calving, but 2.3 pounds with cotton-seed meal. That from four cows, sixty-two days from calving, and having no cotton-seed, lost 3.27 pounds, and that from four cows, fifty-eight days from calving, and having cotton seed, lost 3.3 pounds out of every hundred actually present in the whole milk.

These results show that in the case of centrifugal creaming, a very much larger per cent of the butter-fat present in the milk is obtained, and that without regard to the character of the feed used, whereas in ordinary gravity creaming the character of the food may have a very marked influence upon the quantity of butter obtained from the milk.

LETTERS TO THE EDITOR.

*** *Correspondents are requested to be as brief as possible. The writer's name is in all cases required as proof of good faith.*

On request in advance, one hundred copies of the number containing his communication will be furnished free to any correspondent.

The editor will be glad to publish any queries consonant with the character of the journal.

Throwing-Sticks.

IN the report of the National Museum for 1884 I published a short paper on the "throwing-sticks" of the Eskimo in the Department of Ethnology. The object of this article was to show how the methods and problems of natural history are applicable to the products and apparatus of human industry. Here we had a homogeneous people in blood and language, occupying a zoological area which we call hyperborean, and stretching out to cover Labrador, Greenland, all Arctic Canada, and the shores of Alaska from the Mackenzie district all round to Mt. St. Elias. It was with genuine pleasure that I afterward received from Dr. Seler, Mr. Murdoch, Dr. Stolpe, Dr. Uhle, Mr. Bahnson, Mrs. Nuttall, and Dr. Mortillet their own later contributions upon the same ingenious implement, with the acknowledgements that their publication was stimulated by the Eskimo paper. (Altmexikanische Wurfbretter, von Dr. Ed. Seler, Internationales Archiv für Ethnographie, Bd. iii., 1890; The History of the "Throwing-stick" which drifted from Alaska to Greenland, by John Murdoch, Am. Anthropologist, July, 1890; Ueber Altmexikanische und südamerikanische Wurfbretter, von Dr. Hjalmar Stolpe, in Stockholm, Internat. Archiv f. Ethnog., Bd. iii., 1890; Ueber die Wurfholzer der Indianer Amerikas, von Dr. Max Uhle, Mittheil. der Anthrop. Gesellsch., in Wien, Bd. xvii., n.f. vii., 1887; Ueber südamerikanische Wurfholzer im Kopenhagener Museum, von Kristian Bahnson, Internat. Archiv f. Ethnog., ii., 1889; Mrs. Zelia Nuttall, in a paper read before the Woman's Anthropological Society in Washington, entitled The Atlatl or Spear-Thrower of the Ancient Mexicans, Arch. and Ethnol. Papers of the Peabody Museum, i., No. 3; Les Propulseurs a crochet Modernes et Prehistoriques, Part A., drien de Mortillet, Rev. Mensuelle de l'Ecole d'Anthropologie de Paris, i., 15 Aout, 1891.)

In plate xvii. of my paper two very interesting old specimens are described from the Tlingit or Koloschanaua about Sitka. One of these is figured in Ensign Niblack's monograph (Smithsonian Report, Part II., 1888, plate xxvii, fig. 157). These specimens are very old, are covered with totemic devices, and represent a decayed art passed into its mythic stage. I do not now know of any similar device for throwing spears or harpoons until we get to Mexico, where, as is well shown in the works above quoted, the altatl was one of the commonest weapons. Imagine my great pleasure, therefore, on receiving from Lake Patzcuaro, in Mexico, a modern altatl, well-worn and old looking, accompanied with a gig for killing ducks. The apparatus was bought from the hunter by Capt. John G. Bourke, U.S.A., and may now be seen in the National Museum. The thrower is two feet three inches long, and has two finger-holes projecting, one from the right and one from the left side. In my paper on the Eskimo stick no case of two

finger-holes occurs, and the only example in which it projects from the side at all is from Point Barrow. Since the publication, however, another specimen comes from Cerles inlet, and this is quite puzzling. In Dr. Stolpe's paper you have my Patzcuaro specimen exactly, only mine has no ornament and is a practical every-day implement for killing ducks. The spear-shaft is ten feet long, of slender cane, and has a hole at the after end for the hook of the throwing stick. The gig consists of three iron barbs, for all the world like the Eskimo trident for water-fowl. The problem now is to connect Alaska with Patzcuaro.

O. T. MASON.

Washington, D.C., Oct. 26.

Molecular Motion in the Development of Water Waves.

WHEN waves are developed on the surface of water, whether by something thrown into or moving through the water, or by the friction of the wind blowing along the surface, the water constituting the wave rises up and sinks down, but does not move along the surface. When the friction of the wind is the cause of wave production, or when the waves are produced by any other force exerting a pull or a push in the water, there is some horizontal movement or current; but this current is not wave-motion proper, and is entirely distinct from it. The undulations in a slack rope, vibrated at one end, are true wave-motion, analogous to that which occurs on the surface of water.

If we suppose the water to consist of molecules, each having capacity for its own proper motion, and subject to the force exerted by the earth's attraction and by the pressure of other molecules above it, but free to move with comparatively small friction, the formation of waves becomes very simple. Water under the pressure when the formation of waves is possible, is incompressible, and when a solid body is thrown into or moved through the water so rapidly that the displaced particles cannot get out of the way laterally, some of them are forced up, under the well-known law that motion is in the direction of least resistance. If the body is placed in or drawn through the water slowly enough for the displaced particles to push their way horizontally, none of them are thrown up, and the initial wave is not formed. But time is required for this movement, and when the body is thrown into the water, or moved through it rapidly, the displaced particles are forced to rise up against the force of gravitation, the quantity forced up — that is, the size of the initial wave — being determined by the volume of the body and the rapidity of its movement through the water. If the force is impulsive and not constantly acting, the second wave is less than the first, and they go on diminishing until the force is expended in horizontal motion, and there is an elevation of the surface commensurate with the volume of the immersed body, — the same result precisely that would have been reached without wave-formation if the body had been immersed slowly enough.

When wind first impinges against the surface of still water, the friction pulls up a little of the water in the form of a minute initial wave, but the force being constantly acting, the wave continues to increase in size until the maximum possible from the given friction is reached.

The force of cohesion between the molecules of water is less than the pull of gravitation upon them, for if this were not the case, water would stand up like a solid mass, as ice does, instead of spreading out and flowing, in obedience to the force of gravitation, and continuing to flow until it reaches some substance in which the force of cohesion is sufficient to counteract the pull of gravitation on its molecules, or until the increased cohesion from congelation accomplishes the same result.

While the force of cohesion between the molecules of water is not sufficient to prevent them from moving in obedience to the force of gravitation, it is still considerable, and very great as compared with the force of cohesion between the molecules of air and other gases; and when a portion of the water is forced up against the force of gravitation, the substance continues in mass, and must so continue until subjected to a force sufficient to overcome both gravitation and cohesion.

When the mass lifted up in the formation of the initial wave falls back (as it must do under the constantly acting force of gravitation), with a velocity too great to be expended in horizontal motion, the molecules receiving this impact must rise up as those did which constituted the initial wave, and so on, each wave being the progenitor of that wave which follows it. If the force is impulsive, as when a body is thrown into the water, each wave is the sole progenitor of the wave following; if the force is constantly acting, like the friction of the wind, each wave in producing another is supplemented by the constantly acting force which caused the initial wave.

When the uplifted water falls back on something not so free to move as the molecules of water, — as, for instance, when the water becomes so shallow that the fall is against the bottom, or so thick with grass and water-plants as to impede the free movement of the water, — the wave-formation at once begins to diminish and soon ceases entirely. In short, the waves on the surface of the water are the result of the impact of the lifted-up mass falling back on the free to-move molecules constituting the whole mass with a velocity so great that the force cannot be transmitted horizontally.

In observing the phenomenon on a lake a few miles wide, it is interesting to note that, even in a high wind, the surface of the water near the windward shore is only a little agitated by small ripples; farther out it becomes rougher, and on the lee shore the waves have reached the highest point possible for the extent of surface and force of the wind. The pressure of the wind on the surface of an inland lake is constantly variable, even over comparatively small areas, as every one has observed who has navigated a sail-boat; and as the friction, which is the wave producing force, varies with the pressure, the waves vary in both length and height.

When the wind is high the crests of the highest waves become unable to withstand the impact of the force, and are broken into fragments or spray, forming what we call "white-caps." This phenomenon does not depend entirely on the violence of the wind, nor on the height and volume of the waves, but it depends on the relation between these two. If the waves are very large and oval (and this depends on the nature and action of the force producing them), only the most violent wind can cause white-caps, while if the waves are small but narrow and sharp, a comparatively light wind will develop them. In a portion of the water broken up in the formation of white caps, not unfrequently the force of cohesion is so far counteracted that the water is carried off in the form of spray; the residue of the white-cap not carried off as spray, instead of sinking down with the main body of the wave as in other cases, flows down the farther side of it. Hence the formation of white-caps tends to diminish rather than to increase the size of the waves.

It sometimes happens that the impact of the wind against the water elevated above the surface becomes so violent that it is all blown away as spray, and no waves are formed at all. In January, 1884, I think it was, this phenomenon occurred on Lake Eustis, in Florida. We took passage on the "Mayflower," a little side-wheel steamer of from thirty to forty tons burden, very narrow and long, and low decked, to cross the lake from east to west, the distance being about seven miles. It was blowing a breeze from the west, which caused waves probably a foot high, and sufficient to cause the little steamer to rock perceptibly. A very black cloud came up from the west, meeting us, and between one and two o'clock in the afternoon, when we were about one-fourth of the way across, a storm of wind and rain burst upon us with intense fury. Putting on my overcoat hastily, I at once made my way with difficulty through the wind and rain to the pilot-house, a little coop perched on the front end of the deck, to see that the captain, who was steering, did not lose his presence of mind, and to urge him to hold the head of the boat to the wind, from whatever direction it might come. Finding him cool and self-possessed, I returned to the cabin, another little coop amidships, and found the passengers, eight or ten in number, in great terror. Acting on a suggestion of the captain, I got out the life-preservers, and in less time than it takes me now to write this sentence, each passenger had on one, ready for the plunge which we all knew would come in a few seconds if the wind struck the

boat on the side. When the life-preservers were put on, I opened my satchel and slipped my travelling flask into my overcoat pocket, leaving money and other valuables to their fate, and took position with my wife, who was one of the party, on the deck (a portion of which in rear of the little cabin was sheltered), so as not to be carried down by the boat if it capsized, and held on to a post to prevent being blown overboard. After these precautions were taken, I looked out on the lake, and to my unbounded astonishment the surface was almost perfectly smooth. The moment an incipient wave would rise above the level, the whole of it was carried away as spray by the wind. I saw this occur repeatedly. The spray and rain made it so dark that only the surface of the lake a few feet from the boat could be seen, but as far as could be seen there was violent agitation but no waves, and there was no more rocking of the boat than in a dead calm. This continued for some time, probably an hour after my first observation, when the storm abated, the clouds passed away, and the sun came out; but the wind was still blowing a stiff gale from the same direction, and soon waves from two to three feet high caused the little steamer to roll and jump more than was pleasant.

So far as I am aware, it has not been ascertained experimentally what determines the coefficient of friction of air moving over the surface of water. It is obviously this friction which causes waves in the water when the wind blows, and, like all other friction, it doubtless depends measurably on the direction and violence of the impact. But the air, by a force the operation of which is not clearly understood, and which we call evaporation, is constantly pulling out molecules of water and absorbing them in aqueous vapor.

The units of energy required to transform a pound of water into vapor is a measurable quantity, and according to the law of conservation of energy, the same units of force must be required to do this work, whether the temperature be 100° C., or 0° C., or anywhere between. The time in which the work can be done varies with the temperature, but the units of force expended must remain the same. If this is so, the force exerted in evaporation is immense, and its direction, apparently, is from the surface of the water upwards. It must therefore necessarily operate as a resistance when the air moves across the surface of the water at right angles to this direction, and thus increase friction.

It seems to be analogous to friction between two solid bodies when one of them absorbs the particles rubbed off from the other; the absorption may not increase the friction, but the rubbing-off does. So in this case, the absorption by the air of the molecules or particles of water as aquous vapor may not increase the friction between the air and the water, but pulling them away from the water certainly ought to do it.

From this it would seem that a dry wind, from its greater capacity to absorb aqueous vapor, ought to produce greater friction and higher waves than a damp wind of the same velocity. This appeared to me to be the case with the winds blowing across Lake Harris at my winter home in Florida. The dry winds following the rain-storm seem to raise higher waves than the damp winds preceding the rain and during its continuance; but without facilities or skill for accurately dotermining either the relative humidity or the velocity of the wind, such observations are of no value except to call attention to the subject.

There is another view of the matter which seems to me to be worthy of examination. If the evaporation-pull when air passes over the surface of a liquid is an element in the resulting friction and consequent wave development, we have, in the capacity of certain oils to resist evaporation, an explanation of the phenomenon that pouring oil on the surface of water diminishes the waves. This is indicated by the fact that kerosene oil, which evaporates rapidly, does not seem to have the effect of diminishing wave-formation.

Before this probable difference in friction between liquids which evaporate readily and those which resist evaporation had occurred to me I tried the experiment of pouring kerosene oil on the surface of Lake Harris when it was very rough and a high wind blowing. It had no perceptible effect in diminishing the waves, but a conscious want of skill in conducting the experiment left me in doubt as to whether the failure resulted from that or some other cause. Evaporation takes place more rapidly when the air is not moving, because fresh unsaturated portions of the atmosphere are being constantly brought into contact with the liquid surface; and the theoretical probability that this evaporation, this pulling-away of molecules of water by the air into itself, is an element in the friction between the wind and the water, is certainly sufficient to justify the labor of its experimental determination. It may be that the thorough saturation of the wind blowing across Lake Eustis, in the case above mentioned, was itself an element in preventing the wave-formation: the saturation of the wind may have diminished its friction and consequent capacity for wave development, and the blowing away of incipient waves into spray may have increased the saturation. It was obvious that the quantity of water carried off as spray was not at all comparable to that which rises above the level in waves from a wind of less violence. Taking the normal level as the average between the crest and the trough of the waves, there was much more water above that level when the lake became rough after the hurricane had passed, than appeared to be carried off in spray while no waves were being formed.

There is another element of resistance which must be taken into account in determining the friction between wind and water. The air not only absorbs water in the form of aqueous vapor, but the water holds air (or oxygen obtained from it) in solution. This is the air which the fishes breathe, and under atmospheric pressure and near the surface of the water it is estimated that the air thus held in solution constitutes about one-twentieth of the volume of the fluid. This air can be disengaged from the water. It is this disengagement of the air from the water by the suction of a pump, which renders it impossible for a pump to raise ordinary water to the full height to which the atmospheric pressure will raise a column of water from which air is excluded: when the suction of the pump exerts a pull on the water with air in solution sufficient to raise it to about twenty-seven feet, the air in the water is disengaged and fills the vacuum chamber, thus stopping the further lifting of the water by the vacuum pull. This disengagement of the air from the water goes on in water-pipes also. In a system of water-pipes the disengaged air collects in the most elevated portions of the pipes, and, unless discharged through air-valves, becomes a serious obstacle to the flow of the water.

In ice-making, this air in the water is gotten rid of by distilling the water and recondensing it, or by boiling the water and then freezing it before it has re-absorbed air. If the air is not removed in some way, it remains in the ice in small bubbles, rendering the ice white and porous.

It is certain that the agitation of water either impedes or facilitates the absorption of air into solution. The general impression is that agitating the water aerates it, that is, causes it to absorb air; but when water containing odorous vapor is stirred, they are given off. This and some other phenomena seem to me to indicate that agitation, while it enables water to retain in solution matter heavier than itself, has the opposite effect with matter lighter than itself, and that the tendency of agitation is to cause water to release gaseous matter held in solution. But whether the agitation of the water tends to cause it to take air into solution, or to release air absorbed when the water was less agitated, the process, either of absorption or of release, probably increases friction between the wind and the water, as the surface of the water becomes agitated by wave-formation. This element of friction must be very small when compared with the far greater work of evaporation, but it ought to be taken into consideration in determining the difference in friction between air and water and air and oil.

It has been demonstrated, experimentally, that when water evaporates into air as aqueous vapor the process goes on by molecule after molecule, and not by aggregations of molecules or masses; nor that water absorbs oxygen from the air by taking in each molecule separately; but, according to the accepted theory of diffusion of gases, we must assume that the aqueous vapor resulting from evaporation diffuses into the atmosphere by molecules and not by masses; and the fact that the oxygen of the air dissolved in water is separated from the nitrogen, the molecular con-

stitution of the matter absorbed being different from what it was before its solution, leaves no doubt that that process is molecular also: the oxygen and nitrogen molecules, whose intermixture, through diffusion, constitute the atmosphere, are disassociated, the water taking into solution a much larger proportion of the oxygen. This could not possibly occur if the process of solution were not molecular. If the air is composed of the molecules of oxygen and molecules of nitrogen so intermixed as to constitute a continuous substance, a process which takes more of the oxygen than it does of the nitrogen is necessarily molecular.

It seems, therefore, that we are authorized to conclude not only that the waves themselves are the result of motion of the molecules constituting the water, and not of masses of such molecules, but that when wind causes the waves, its friction, in part if not entirely, is due to the passage of molecules from one fluid into the other. DANIEL S. TROY.

Montgomery, Ala, Oct. 23.

Rain-Making.

AS Professor Hazen, in his letter published in *Science* of Oct. 16, garbles the quotation from Plutarch which is relied on to prove that the ancients had the same notion in regard to rains following battles that prevails at the present time, I beg leave to give the passage entire, for it is only by a consideration of the whole that his meaning can be arrived at. Plutarch says, in his life of Marius, speaking of the defeat of the Ambrones by the Romans:

'The Romans pursuing, either killed or took prisoners above a hundred thousand. Other historians give a different account of the number of the slain. From these writers we learn that the Massilians walled in their vineyards with the bones they found in the field, and that the rain which fell the winter following, soaking in the moisture of the putrefied bodies, the ground was so enriched by it that it produced the next season a prodigious crop. It is to be observed, indeed, that extraordinary rains generally follow after great battles; whether it be that some deity chooses to wash and purify the earth with water from above, or whether the blood and corruption, by the moist and heavy vapors they emit, thicken the air, which is liable to be altered by the smallest cause."

Now, if we take by itself the statement that "extraordinary rains generally follow after great battles," it would appear, indeed, that the ancient ideas on this subject were identical with those prevailing in modern times. But if we ask the question, "How long after the battles did the rains occur to which Plutarch alluded?" and look for our answer in the context, we shall see, as I said in my letter in *Science* of Oct. 7, that the notions of the former on the subject appear to have been wholly different from those of the latter. When did the rains follow the battle between the Ambrones and the Romans? In the winter following. When did rains follow any other battles that Plutarch had in mind, or when did he think they followed? After the bodies of the dead had putrefied. How soon could the "blood and corruption" — especially the corruption — emit "moist and heavy vapors?" Not under a week. How soon could "some deity wash and purify the earth with water from above?" Not under several months.

It matters not how erroneous Plutarch's ideas were as to why rains followed after battles. It is not his conclusions with which we have to deal, but we are trying to find out what he supposed the facts to be on which he based them. In doing this we have no right to assume as facts anything that is inconsistent with his view of the case.

Professor Hazen quotes the opinion of another rain-maker in opposition to my own. He might also have quoted me against myself. In an article written by me and published in the *Golden Age* of May 11, 1872, and which is also copied into the appendix to the revised edition of "War and the Weather," occurs the following passage:

"If great noises cause rain, some other less expensive way may be devised to produce them. It was noticed, even in ancient times, that great rains followed battles, and it is not impossible that the shouts of a great multitude, with the clashing of metal on metal, may produce the same effect upon the air as the firing of cannon. Should all the inhabitants of a city at a given hour unite in creating an uproar with hands and voices, it would seem to one in our day as though the world were returning to barbarism; but in the higher civilization of some age to come, this may perhaps be a common occurrence."

The other rain-maker referred to has evidently adopted this idea without having made any more critical examination of the passage quoted from Plutarch than I had done when the above was written. But though I have changed my mind in regard to the meaning of this passage, it would be going too far to say that ancient battles did not immediately produce rain, and that the above does not furnish the true explanation of the phenomenon. I only affirm that Plutarch did not say that rains immediately followed great battles, and that the inference that he thought they did cannot be drawn from what he does say. I contend further that, even if the ancients thought that battles produced rain, they may have been wrong, while the moderns may be right in that opinion. Coincidences sometimes occur in thought as well as in action and events.

In speaking of the battles of the late war, and their supposed effect upon the atmosphere, Professor Hazen says, "Mr. Powers thinks that the currents of the atmosphere do not travel at the rate of twenty to fifty miles per hour, or, at least, during these battles they did not do so." This is hardly a fair statement of my position. I think it very probable that portions of two currents moving in nearly opposite directions, in mingling together, lose to a great extent their original motion, and take on a circular motion, moving for a time neither very far east nor very far west. I think that in this way the influence of the concussions may remain in the vicinity of the firing until enough air of different temperatures has mixed together to develop a rain-storm, and that then the storm will move eastward along with the current that supplies the greater portion of the moisture that forms the rain.

Professor Hazen repeats his statement that "one thing seems very certain, that absolutely no rain can be obtained out of a dry atmosphere," and eliminates from it the word "seems." It is not apparent how this helps it as an argument against the artificial-rain theory. According to my understanding of his first article, he did not state this as an abstract idea, but in order to show how unreasonable it was, in his view, to expect to produce rain by concussion in certain states of the atmosphere; and by "atmosphere" I naturally understood him to mean the same thing that he would mean if he were speaking of measuring the humidity of the atmosphere with his instruments. My contention is that there is nothing unreasonable in expecting to produce rain, however dry such air may be, for we are constantly receiving, by the vehicle of air-currents, supplies of aqueous vapor from the tropical portion of the Pacific Ocean; and these currents and the vapor they bring occupy a high altitude, and there the clouds and rain are formed.

Professor Hazen says, "It certainly is not a fact that two currents pass in opposite directions near the point of formation of our storms." How does he know this? He must admit that there is a current moving constantly from west to east or from south-west to north-east. How does he know what there is above this current? Professor Maury gives very strong reasons for believing that there is a polar current there flowing in nearly the opposite direction. Has any one ever given as good reasons for believing to the contrary? Professor Maury's theory was not evolved from a few isolated facts, but from a comprehensive knowledge of the winds throughout the whole world, or so much of it as could be reached by navigators. Has his theory of the circulation of the atmosphere ever been overturned, or even seriously attacked? When I speak of air-currents, one bringing tropical moisture and the other polar cold, I am not drawing upon my own imagination for props to support the theory of artificial rain production, but I am availing myself of the result of investigations and deductions by one who, as a man of science, was a peer to any whom this country has ever produced.

Delavan, Wis., Oct. 19. EDWARD POWERS.

AMONG THE PUBLISHERS.

LOVERS of the camera will read with interest Ellerslie's Wallace's article on "Orthochromatic Films and Plates," in *Outing* for November.

— Some time ago we noticed the first volume of a work entitled "Hermetic Philosophy," and the second volume has now appeared from the press of Lippincott. It purports to be written by "Styx, of the H. B. of L.," and in style and character is a fit companion of its predecessor. It is impossible to give an intelligible idea of the book, for the simple reason that the book itself is not intelligible; but an extract from it will perhaps give our readers some notion of its general character. Speaking of life, the writer says: "A germ of life enters the matrix of its conception as a secondary point in a line of projection, and this line is projected from a paternal fountain of both intelligence and life; and the germ, in order to attain to the freedom of a point, must be stripped of its affiliations with special measurements. When thus liberated, it has simply cast off the physical and resumed its normal psychical habitude. Then in its freedom it may affiliate with the energies which flow in a line, even in those which follow the lunar rays of light; we say in the lunar, because such an entity is yet of a psychical consistency" (p. 86). Elsewhere we read that "we have in us earth, water, air, and fire, which yet are neither earth, water, air, nor fire, nor anything truly" (p. 56); and in our humble opinion this so-called "hermetic philosophy" is neither philosophy, science, nor religion, nor "anything truly."

—"Higher Education in Indiana" is the title of a monograph by Professor James Albert Woodburn of the Indiana University, published by the government Bureau of Education as Circular of Information No. 1, 1891. It contains an outline of the free common school system of Indiana; a brief account of that State's educational history in the development of its common schools; and a historical account of the origin, growth, and development of Indiana's various institutions for higher education, together with a glance at their present condition. The monograph makes a volume of two hundred pages.

— The October number of the *Quarterly Journal of Economics*, which has been delayed for a week or two after its usual date of publication, has made its appearance, with a varied table of contents. Noteworthy among the articles are a paper by Bishop Keane, rector of the Catholic University of America, on the relation of the Catholic Church to the social questions of the day; another by Professor William Carey Jones of California on the Kaweah Co-operative Colony in that State; and one by Professor Bemis of Vanderbilt University on the action of trades-unions with respect to apprentices. Several writers continue the discus-

sion of points of economic theory, and there is a short paper on the Toronto street railway. A note announces a forthcoming reprint of Cantillon's celebrated essay on commerce.

— Professor W. O. Atwater of Wesleyan University contributes an article to the November *Century* on "The Food Supply of the Future," the first in a series which will have especial value to farmers. The writer believes that the doctrine of Malthus — that the time will come when there will not be food enough for the human race, owing to the theory that population increases in a geometrical and food-supply in an arithmetical ratio — is one which need never give the world any uneasiness, owing to the great advances that are being made in chemistry. Science has shown what are the essential factors in vegetable production, and plants can now be grown in water or in sand by adding the proper chemicals. Professor Atwater gives the result of an interesting experiment recently made in his laboratory. Sea sand was brought from the shore of Long Island Sound. To divest it of every possible material which the plant might use for food except the sand itself, it was carefully washed with water and then heated. It was put into glass jars, water was added, and minute quantities of chemical salts were dissolved in it. Dwarf peas, planted in this sand, grew to a height of eight feet, while peas of the same kind, planted by a skilful gardener in the rich soil of a garden close by, reached a height of only four feet.

— In *Lippincott's Magazine* for November, two articles that will be read with interest are "The Evolution of Money and Finance," by J. Howard Cowperthwait, and "The Restoration of Silver," by John A. Grier. The first is a strong plea for gold only as a standard measure of value. Mr. Grier, from the bi-metallist's point of view, attacks this article, and puts in a plea for the equal use of both gold and silver as a measure of value. The "silver question" is one which every American should understand, and the best way to understand it is to look at both sides of the question.